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Aggregate Resources Inventory of Mersea, Gosfield North and Gosfield South Townships

Essex County
Southern Ontario

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CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in cooperation with the Coal Association of Canada.

Aggregate Resources Inventory of Mersea, Gosfield North and Gosfield South Townships
Essex County

By Staff[1] of the Engineering and Terrain Geology Section

1. Project Supervisor: I. Szoke; field work and report by: R. Gorman; compilation and drafting by Staff of the Aggregate Assessment Office. The Mineral Resources Staff of Chatham and Aylmer Districts and Southwestern Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Abstract

Figure 1. *Key map showing the Location of Mersea, Gosfield North and Gosfield South Townships, scale 1:1 800 000.*

This report includes both an inventory and evaluation of sand and gravel, as well as bedrock resources, in Mersea, Gosfield North and Gosfield South Townships. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

In the report area, two areas containing significant amounts of sand and gravel have been selected as Resource Areas of Primary Significance. Selected Resource Areas 1 and 2 consist of glaciolacustrine beach deposits related to the abandoned shorelines of glacial Lakes Whittlesey and Warren. The Primary Resource Areas cover 5900 acres (2390 ha), exclusive of licenced properties. Approximately 3700 acres (1500 ha) are considered to be available for extraction. The available areas contain possible resources of 138 million tons (125 million tonnes) of sand and gravel. The available portions of the selected areas represent 10 percent of the total area of sand and gravel deposits in the townships and 16 percent of the total resource tonnage.

In addition to these deposits, an extensive beach deposit related to glacial Lake Grassmere has been selected as a Resource Area of Secondary Significance. This deposit is relatively unexploited but may contain limited amounts of low–specification aggregate suitable for local use. Although this deposit is not considered the "best" resource, it should be considered part of the report area's total aggregate supply.

The surficial deposits are underlain by Devonian limestones and dolostones of the Amherstburg, Lucas and Dundee Formations and shale and limestone of the Hamilton Group. Although the Lucas Formation is suitable for use in granular base course and sub–base course materials, excessive drift thickness prevents the formation from being selected for possible resource protection.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock–derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road–building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1986, the total tonnage of mineral aggregates extracted was 136 million tons (123 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1988).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed–location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision–m ers in protecting the public well–being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock–derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man–made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel– and sand–sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25– to 100–pound (11– to 45–kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition, and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above–named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one–foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned

pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock–derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one–foot (0.3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (see Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

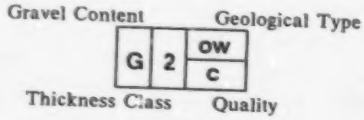
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel–sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark red shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large–scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 (greater than 20 feet (6 m) thick), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub–base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road–building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a re-

duction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendices B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C; Hot–Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man–made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man–made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops

or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III – Assessment of Aggregate Resources in Mersea, Gosfield North and Gosfield South Townships

LOCATION AND POPULATION

The report area combines three townships: Mersea, Gosfield North and Gosfield South Townships. They occupy a total area of 122,733 acres (49 670 ha) in the southeastern corner of Essex County, southwestern Ontario. The townships are shown on portions of the Essex (40 J/2), Romney (40 J/1) and Pelee (40 G/15) map sheets of the National Topographic System at a scale of 1:50 000. Point Pelee National Park is located within the report area and offers a fascinating blend of marsh, forest, fields and beach environments.

Since 1972, the population of the townships (exclusive of the incorporated towns) in the report area has remained relatively stable, experiencing only minor fluctuations during a period of moderate growth. The total population (excluding the incorporated towns) increased about 6 percent from 18,626 in 1972 to 19,727 in 1985 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974; Ontario Ministry of Municipal Affairs 1987).

The towns of Leamington, Kingsville, and Essex are the major local trade and retail centres in the report area. The joint populations of these towns reached 23,890 in 1985 (Ontario Ministry of Municipal Affairs 1987). Figures from previous years indicate that these towns, and particularly the town of Essex, have experienced substantial growth (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). Other population centres within the report area include the village of Wheatley (Kent County) and the unincorporated settlements of Blytheswood, Mount Carmel, Cottam and Ruthven. The remainder of the population in the townships is rural–farm or rural–residential. The summer resident population has also undergone a substantial increase over the years, especially along the shoreline between Point Pelee National Park and Sea Cliffe Park. Additional cottage development occurring in the area adjacent to Cedar Beach has also led to an increase in seasonal–recreational inhabitants. Population projections for Essex County as a whole indicate a possible population increase up to 31 percent by the year 2001 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976).

The demand for both road–building and construction aggregate will likely increase if the present permanent and seasonal growth rates in the townships and surrounding areas continue. Although rural–residential development tends to increase the consumption of aggregates, it may also, in some instances, restrict access by sterilizing potential mineral aggregate resource areas. Many of the mineral aggregate deposits in the report area are already sterilized by intensively cultivated vegetable crops, such as tomatoes, corn and cucumbers.

The townships are served by a grid network of paved and gravel–surfaced township and county roads. King's Highways 3, 18 and 77 serve as haulage routes to market centres. Lines of Canadian National Railways and CSX Transportation Incorporated (CSXT) (formerly the Michigan Central Railway and Chesapeake and Ohio Railway Lines) serve the report area. The southern boundaries of Mersea and Gosfield South Townships are served by ship traffic from the Great Lakes. Extensive docking facilities are available at the towns of Kingsville and Leamington.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Approximately 23,000 to 10,000 years ago, during the Late Wisconsinan Substage of the Pleistocene Epoch (informally known as the "Great Ice Age"), lobes or submasses of the Laurentide Ice Sheet advanced out of the basins of the Great Lakes and joined together to cover southern Ontario. The lateral extent of the ice lobes and the positions of their margins underwent numerous fluctuations until approximately 10 000 years ago when the ice melted. The physiography and distribution of surficial materials in Mersea, Gosfield North and Gosfield South Townships, including the sand and gravel deposits shown on Map 1, are largely the result of the repeated advance and melting back of the margins of the Huron and Erie ice lobes.

Mersea, Gosfield North and Gosfield South Townships contain parts of two physiographic regions as described by Chapman and Putnam (1984): the Essex Clay Plain subregion of the St. Clair Clay Plains, and the Erie Spits. The Essex Clay Plain represents an area of generally low relief positioned between the basins of Lake Erie and Lake St. Clair. The subregion is essentially a flat till plain and represents the greatest percentage of land area in the townships. Nearly all rivers and creeks drain on a very mild gradient northward towards Lake St. Clair. Dredged ditches and tile under–drains are common throughout the area and provide drainage to improve crop growth conditions. Point Pelee is the most westerly sand spit of the Erie Spits physiographic region and marks the most southern point in the townships.

The continuity of the low–relief plain is interrupted by the Leamington Moraine (Chapman and Putnam 1984, p.44). This high morainic hill stands about 100 feet (30 m) above the surrounding plain, and its shoulders and flanks are mantled with beach deposits from glacial Lakes Whittlesey and Warren. The interlobate aspects of this moraine are complex and poorly understood. Taylor (1913) describes the Essex Moraine and the Kingsville boulder belt, two features which occur in the report area, but with the exception of the fragment of the moraine at Leamington, both features were omitted by Chapman and Putnam (1984, p.44) because the moraine is difficult to distinguish in the field, and the low knolls of the boulder belt are so scattered.

The report area was affected by competing glacial lobes that flowed out of the Lake Huron and Lake Erie basins. The flow patterns were very complex and changed frequently during the Wisconsinan Substage (Dreimanis and Goldthwait 1973). The following description of glacial events in the townships is based on work by Leverett and Taylor (1915), Dreimanis (1969), Dreimanis and Goldthwait (1973) and Dreimanis (1977).

Prior to 23,000 years ago, the Huron lobe advanced to the maximum Wisconsinan extent in Ohio and Indiana. The first major retreat of the Huron and Erie lobes occurred about 17,000 years ago, during the Erie Interstadial. Following the Erie Interstadial, the rapid glacial readvance of the Port Bruce Stadial produced tills rich in clay and silt from the lacustrine sediments of the Huron and Erie basins (Dreimanis 1961). The oldest glacial deposits mapped by Vagners (1972) in the report area are two till units that may have been deposited during this readvance. The oldest of the tills is a clayey silt till that is found throughout the report area. The youngest till, described as a sandy loam till (Vagners 1972), is located adjacent to the highest point in the report area. These tills have very little value as aggregate because of their excessive silt and clay content. However, clay has been derived from a number of sources in the clayey silt till unit for use in the drain tile and brick industry. A tile plant has operated since 1870, north of Kingsville (Guillet 1967).

Following the Port Bruce Stadial, rapid glacial retreat occurred during the Mackinaw Interstadial. Thin glaciofluvial outwash deposits deposited by sediment–laden meltwaters discharging from the retreating glacier are common in the townships. These deposits consist largely of pebbly medium sand and in some localities have been modified by subsequent lacustrine action (Vagners 1972).

With the onset of the Mackinaw Interstadial, and the minor readvances during the next 500 to 1,000 years that followed, a sequence of glacial lakes from Lake Maumee to Early Lake Erie developed (Leverett 1902; Hough 1958, 1963 and 1966; Dreimanis 1966, 1967; Sly and Lewis 1972). These lakes ponded between high ground to the south and west of present Lake Erie and glacial ice to the north and east. During this time deep water sediments consisting of silt and clay were deposited in the Kingsville–Leamington area (Vagners 1972). Lacustrine plain sediments consisting of silty, fine to medium sand were deposited in the shallower parts of the lake, especially near Leamington. The fineness of their gradation limits the potential of these deposits as significant aggregate sources.

About 13,000 years ago, during the Port Huron substage (Wayne and Zumberge 1965), shorelines and associated beach deposits of glacial Lake Whittlesey were established in the report area. Lake Whittlesey later gave way to glacial Lakes Warren and Grassmere. The Lake Whittlesey and Warren beach deposits have been indicated as important sand and gravel resource areas. In particular, the deposit located immediately west of Leamington represents a major aggregate resource area for the townships. The material found in these deposits is primarily fine gravel with interstratified medium to coarse sand.

A period of rapid retreat followed and ice lobes gradually vacated the Erie basin and parts of the adjacent Michigan, and Ontario basins. New outlets opened which allowed lake levels to drop to the Early Algonquin Lake Stages. With even further retreat of the ice margin about 12,600 years ago, Lake Erie water levels fell as it drained over the Niagara Escarpment into Lake Iroquois via the modern Niagara River (Sly and Lewis 1972). This marked the end of glacial activity in the Erie basin and the beginning of the development of Early Lake Erie.

Postglacial and erosional processes have been of some importance in changing the land surface of the report area. Point Pelee represents a modern spit formed by the interaction of longshore currents carrying sand from eroded shore bluffs from the east and west. Wave and current action along the report area's shoreline have created modern beaches of gravel and gravelly sand (Vagners 1972). Impounded bogs, marshes and swamps consisting of peat, muck and marl have been established at Point Pelee. Dune features are commonly formed on lacustrine sand both east of Leamington and on Point Pelee.

EXTRACTIVE ACTIVITY

Mersea, Gosfield North and Gosfield South Townships were designated under the Pits and Quarries Control Act in August 1973. Prior to that time numerous pits were worked throughout the report area. Extractive activity was centered in the gravels and gravelly sands related to the abandoned shorelines of glacial Lakes Whittlesey and Warren. A substantial volume of aggregate has been removed from these pits and many of the pits are currently depleted or are near depletion. The majority of the pits

located in the large beach deposit located west of Leamington have been given a low use rating according to criteria established by the Ontario Ministry of Transportation. Most of these properties contain fine–grained aggregate suitable for the production of Granular Base Course (G.B.C.) B and C.

At the present time twenty–six sand and gravel pits are licenced for extraction in the townships. The total area licenced for extraction in the report area is 880.61 acres (356.38 ha). Records of the total annual production from all licenced sources show that the average annual production over the eleven–year period from 1974 to 1984 was 905,000 tons (820 000 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 illustrates the location of sand and gravel deposits in Mersea, Gosfield North and Gosfield South Townships. The total area occupied by these deposits is approximately 37,000 acres (15 000 ha), or 30 percent of the total area of the townships. The deposits contain possible resources of 860 million tons (780 million tonnes). However, many of the deposits contain fine–grained materials which have very limited potential for use as road–building or construction aggregate.

Two beach deposits related to glacial Lakes Whittlesey and Warren have been selected as Sand and Gravel Resource Areas of Primary Significance. One of these deposits has been, and is being extensively worked and the remaining sand and gravel in the pits is of limited use. As a result, high–quality aggregate has to be imported in order to meet road–building and construction demands. The Selected Sand and Gravel Resource Areas of Primary Significance have a total of 3700 acres (1500 ha) potentially available for extraction, containing possible sand and gravel resources of approximately 138 million tons (125 million tonnes). The available portions of the selected areas represent 10 percent of the total area of sand and gravel deposits in the report area, and 16 percent of the original tonnage.

A further 2500 acres (1010 ha) have been identified as a possible Sand and Gravel Resource Area of Secondary Significance. The area is located in the north–central part of the study area and consists of a beach deposit related to glacial Lake Grassmere. Although this deposit is not the "best" resource in the report area, it should be considered an important part of the township's long term total aggregate supply.

Because of a general lack of crushable aggregate, crushed stone products such as G.B.C. "A" stone, 3/4 inch (19 mm) concrete stone, 3/4 inch (19 mm) clear stone, asphalt stone and 3/8 inch (9.5 mm) chips have to be imported into the report area. According to Statistics Canada (1980, 1983), imported aggregate from Michigan and Ohio arriving at the Kingsville docks in 1980 totalled 10,466 tons (9497 tonnes), increasing to 88,235 tons (80,068 tonnes)in 1983. Peat–Marwick & Partners and M.M. Dillon Ltd. (1981) and Koniuszy and Katona (1981) indicate that there are three major sources of imported aggregates for Essex County: 1) aggregate transported from the U.S.A. by water and by road; 2) granular base aggregates supplied by road from the McGregor and Amherst quarries near Amherstburg; and 3) crushed stone supplied by water from a quarry located on the south shore of Manitoulin Island. A substantial portion of the approximately 275,500 tons (250,000 tonnes) of crushed stone shipped through the Kingsville docks in the Chatham District of the Ministry of Natural Resources from 1981 through 1984 came from the quarry on Manitoulin Island.

SELECTED SAND AND GRAVEL RESOURCE AREAS 1 AND 2

Selected Sand and Gravel Resource Areas 1 and 2 consist of two glaciolacustrine beach deposits which are part of the abandoned shorelines of glacial Lakes Whittlesey and Warren. Both beach deposits are established on the sides of the Leamington moraine, immediately west of Leamington and north of Ruthven, in the south–central part of the report area. Although the sand and gravel found within these deposits is not of the highest quality, the deposits have traditionally been the largest and most important sources of fine gravel within the townships. Pits containing crushable material are virtually non–existent in the area (Deike 1972). There has been a substantial history of sand and gravel extraction from Area 1 since the early 1900's. Consequently, in many of the sources the gravel is now depleted and sand predominates.

Twenty–four pits in Resource Area 1 and one pit in Resource Area 2 are currently licenced to operate under the Pits and Quarries Control Act. Twelve identified unlicenced sources have also operated in the two Selected Resource Areas. The faces in these pits range in height from 5 to 70 feet (1.5 to 21 m) and expose variable gravel contents ranging from less than 10 to 40 percent. Overgrown faces and water filled floors typify more than 40 percent of the sources in Areas 1 and 2. During field investigation fresh excavations made in some of the sources generally revealed subangular to well rounded fine gravel with interstratified medium to coarse sand. Faces in pit nos. 15 and 22 revealed well sorted interlayers of openwork granules with common imbricated shingle layers. Because of the presence of a high water table (Hewitt and Cowan 1969) dragline operations have been carried out in many properties located in Mersea Township, to extract material from below the water table. Test holes GM–TH–1 and GM–TH–2 showed the presence of 24 to 45.5 feet (7.3 to 13.9 m) of sand below a 1 to 9 foot (0.3 to 2.7 m) till layer overlain by 4 to 5.5 feet (1.2 to

1.7 m) of sand (Table 7). Test holes GM–TH–3 to GM–TH–7, drilled in various pits, revealed the presence of additional sandy material below the pit floors. A geophysics traverse line (GM–GT–1) completed on the floor of pit nos. 3 and 4 (Map 1) confirmed the presence of an additional 8 feet (2.4 m) of fine aggregate before encountering till (Table 8).

Aggregate suitability data obtained from the Ministry of Transportation indicate that in the past these deposits have been capable of supplying quantities of fine–grained aggregate acceptable for G.B.C. B and C. In 1984, channel face samples taken in the licenced properties by staff members of the Chatham District Office of the Ontario Ministry of Natural Resources, were analysed by the Materials Testing Laboratories of the Soils and Aggregates Section of the Ministry of Transportation, in London, Ontario. The results of the grain size analyses indicate that the sampled aggregate generally lies within the acceptable limits for G.B.C. B and C (Figures 2a to 7a). In most of the sources, the sand fraction of the aggregate requires blending in order to produce high–specification fine aggregate products such as hot–laid sand (Figures 2b to 7b). The presence of clay and silt represent only a minor problem in most of the sources. However, washing and sizing plants have been established in larger operations to better process extracted material. For instance, sand is brought from other sources to pit no. 8 where it is washed and graded hydraulically by means of gravity separation.

Magnesium Sulphate soundness tests conducted on fine and coarse aggregate samples from the licenced properties resulted in a wide range of readings. Numbers ranged from acceptable losses of 3 percent to unacceptable losses of greater than 21 percent. High percentage loss results may be attributed to the presence of shale and chert originating from the underlying shale– and chert–bearing formations (Ingham and Koniuszy 1965).

Selected Areas 1 and 2 occupy 5900 acres (2390 ha), exclusive of the licenced properties. Cultural constraints and previous extraction reduce the potentially available area to 3700 acres (1500 ha). The estimated average thickness of usable material in Areas 1 and 2 is 15 feet (5 m) based on pit face heights, test hole depths and water well data. Therefore, the sand and gravel resources total approximately 138 million tons (125 million tonnes). Road access to Areas 1 and 2 is provided by King's Highways 3, 18 and 77 and a network of paved and gravel–surfaced county and township roads. A rail line of CSX Transportation Incorporated crosses Areas 1 and 2, immediately west of Leamington.

Sand and Gravel Resource Areas of Secondary Significance

An extensive beach deposit related to the abandoned shoreline of glacial Lake Grassmere has been selected at the secondary level of significance. This deposit is located immediately north of Resource Area 1 and may provide alternate extractive sites to supplement those provided by Areas of Primary Significance. During field investigations, two 10–foot (3 m) dugout excavations made in the deposit revealed minor fine gravel with interstratified silty fine to medium sand. Although the material in this deposit is probably not suitable for high–specification aggregate use, limited amounts of low–specification aggregate suitable for local use in the area may be available.

Buried Sand and Gravel Deposits

A study prepared for the Ontario Ministry of Natural Resources (Proctor and Redfern Limited and Gartner Lee Associates Limited 1977) indicates that in Essex County, the only known surficial aggregate resources occur within glaciolacustrine beach deposits. These deposits are usually thin and generally contain sandy aggregate with little crushable material. Some of the most significant beach deposits occur within Mersea, Gosfield South and Gosfield North Townships. As discussed earlier, a substantial volume of aggregate has already been removed from a number of pits located in these deposits, and the remaining fine–grained aggregate is generally suitable for use in granular base course products.

The general lack of crushable aggregate in Essex County and in adjacent Kent, Elgin and Lambton Counties (Proctor and Redfern Limited and Gartner Lee Associates Limited 1977) has led to considerable interest in a number of possible sources of buried aggregate. Buried aggregate has been extracted from below a thin veneer of till by local pit operators in the Leamington area. The relationship between the deposition of these buried sediments and the Leamington Moraine has not been established. The sediments may have been deposited in an ice–contact delta or an outwash fan feature formed prior to the deposition of the overlying till.

The buried sediments are exposed in licenced pit 2. Faces in this pit reveal glacial Lake Warren beach sediments overlying a thin discontinuous till unit which in turn overlies approximately 10 to 20 feet (3 to 6 m) of pebbly, medium to coarse shaley sand. In places, the estimated gravel content is less than 20 percent. The material may be suitable for G.B.C. B and C. Blending would be required in order to produce high–specification fine aggregate products. Test holes completed northwest of Leamington (Table 7) generally revealed considerable depths of gravelly sand below the till unit. Water well data in the Olinda area also indicate the presence of substantial depths of buried material.

The potential resources in this buried deposit are relatively unexploited. Geological boundaries could not be established because of the complexity of the underlying till unit and general lack of subsurface data. An overlying till unit and glaciolacustrine

beach sediments makes exploration for usable material very difficult. Future subsurface exploration may uncover high–quality aggregate and further increase the resource potential of the area.

BEDROCK GEOLOGY

Glacial sediments in Mersea, Gosfield North and Gosfield South Townships are underlain by Lower to Middle Devonian strata consisting mainly of limestones, dolostones and shales. The Lower Devonian Amherstburg Formation of the Detroit River Group is the oldest bedrock unit that subcrops in the report area. It occurs in a narrow band along the shore of Lake Erie between the towns of Leamington and Kingsville. The unit also subcrops in the southwestern part of Gosfield South Township and continues westward to Amherstburg where it is exposed in the Amherst quarry in Malden Township. The formation consists of approximately 161 feet (49 m) of dark coloured, finely crystalline limestone and dolostones, characterized by zones with bituminous and cherty natures (Sanford 1969; Telford and Russell 1981). Only small portions of the formation are exposed in quarries in southern Ontario and there is little available information on its suitability as a source of crushed aggregate. Grey chert nodules occurring within the unit could severely restrict the use of the rock for the production of crushed stone products.

Conformably overlying the Amherstburg Formation are the Lower to Middle Devonian dolostones and limestones of the Lucas Formation of the Detroit River Group. The Lucas Formation occurs in a broad belt extending from Point Pelee National Park to the western part of the report area. In Essex County the unit can be subdivided into undifferentiated Lucas Formation and the Anderdon Member of the Lucas Formation. Undifferentiated Lucas Formation consists of thin– to medium–bedded, light brown to grey–brown, finely crystalline, poorly fossiliferous dolostone with minor chert, dark bituminous laminations, and local mottling (Uyeno et al. 1982). This unit has been quarried near Amherstburg for granular base course and sub–base course materials. Problems with excessive fines, and high absorption, soundness and abrasion losses have been experienced with some of the material from the undifferentiated Lucas Formation at the McGregor quarry in Anderdon Township (Koniuszy and Katona 1981).

The Anderdon Member of the Lucas Formation consists of a very high purity calcium limestone which has been extensively quarried near Ingersoll and Amherstburg for use in the production of flux stone, chemical lime and portland cement. Rock from the Anderdon Member is of excellent quality for all aggregate products used in highway construction except Hot–Laid No. 1 (Koniuszy and Katona 1981). The stone is also suitable for concrete aggregate (Hewitt 1975). Kennette Contracting Company Limited (Licenced pit no. 21) utilizes the by–product from Allied's chemical lime operation at the McGregor quarry. The unused crushed product from the top bench of the quarry that passes the 1 inch (25.4 mm) sieve is screened and washed for crushed stone products such as 3/4 inch (19 mm) crushed G.B.C. "A" stone, 3/4 inch (19 mm) No. 4 concrete stone and 5/8 inch (16 mm) crushed A and B stone. Additional areas of high purity limestone may exist elsewhere within the Lucas Formation in the report area. Selected coring and testing would be necessary in order to establish the extent and the suitability of the rocks from this formation for high–specification crushed stone aggregate products.

The Middle Devonian Dundee Formation underlies a substantial part of the report area extending in a wide band from Point Pelee National Park to the Town of Essex. The formation overlies the Lucas Formation and varies considerably in thickness. The unit is a medium– to thick–bedded, dark brown, fossiliferous, micritic limestone. It is an absorptive limestone that contains bituminous laminations, shaly partings, chert nodules and lenses of coarse–grained limestone (Uyeno et al. 1982). The formation has been extensively quarried at St. Marys for use in the production of portland cement. However, at Amherstburg, the formation is not of suitable quality for this use. Quarrying of the unit has occurred near Amherstburg and on Pelee Island for granular base course and sub–base uses but it is unacceptable for hot–laid and concrete uses (Koniuszy and Katona 1981). The suitability of the rock for use in the production of crushed stone products within the report area can only be established by appropriate testing.

The Hamilton Group is the youngest Paleozoic unit that subcrops in the area, and it is found in the northeastern part of Mersea Township. Formations of the Hamilton Group are composed of grey shales with interbeds of crystalline and cherty limestone (Telford and Russell 1981). The group has six formations, but only the Arkona Formation is of commercial value. It has been extracted at Thedford and near Arkona for the production of drainage tile and brick. One thin stratum of limestone in the Hamilton Group has been found acceptable for Granular Base Course A, however, rock from the unit will not meet quality requirements for structural concrete or any hot–laid uses (Deike 1982).

Devonian strata in this part of southwestern Ontario have a gentle regional dip of approximately 30 to 45 feet per mile (6 to 9 metres per kilometre) towards the southeast (Winder & Sanford 1972; Uyeno et al. 1982). The overburden in most of the report area is quite thick, except for a few isolated locations identified from water well and natural gas and/or oil well data. Quarrying of these units is, therefore, not practical.

SUMMARY

The sand and gravel deposits of Mersea, Gosfield North and Gosfield South Townships are the product of glacial activity that took place during the Great Ice Age, as well as the postglacial deposition of dune sand. Presently, proven resources of crushable material are scarce in the report area. Two large beach deposits in the Leamington area have been selected for possible resource protection at the primary level of significance. In the past, these deposits supplied quantities of fine gravel capable of meeting local demands for low specification products. Recently, these deposits have been considerably constrained by use suitability and competing land uses. High quality aggregate has to be imported from alternative sources in the United States and other parts of Ontario to meet many road–building and construction purposes.

In addition, an extensive beach deposit located in the north–central part of the report area has been selected for secondary resource protection. This deposit can be considered as part of the total aggregate supply potential.

The report area is underlain by bedrock of Lower to Middle Devonian strata consisting mainly of limestones, dolostones and shales. Thick drift cover restricts quarrying of these formations. The report area must rely totally on surficial sand and gravel deposits and imported crushed stone products for road–building and construction purposes.

Enquiries regarding the Aggregate Resources Inventory of Mersea, Gosfield North and Gosfield South Townships should be directed to the Aggregate Assessment Office, Ontario Geological Survey, Mines and Minerals Division, Ontario Ministry of Northern Development and Mines, Room M1B–45, Macdonald Block, Queen's Park, Toronto, Ontario, M7A 1W4, [Tel. (416) 965–1663], to the Resident Geologist, Mines and Minerals Division, Ministry of Northern Development and Mines, Box 5463, 659 Exeter Road, London, Ontario, N6A 4L6 [Tel. (519) 661–2773], or to the Chatham District Office, Ministry of Natural Resources, Chatham, Ontario, N7M 5L8 [Tel. (519) 354–7340].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.*

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
2	S-LB	7100 (2900)	265 (240)
	S-LP	4800 (1940)	180 (163)
	S-WD	75 (30)	2 (2)
	S-WD-LP	1120 (455)	42 (38)
3	S-LB	2800 (1130)	56 (51)
	S-LP	6100 (2470)	122 (111)
	S-WD	20 (8)	<1 (<1)
4	S-LB	10 (4)	<1 (<1)
	S-LP	1170 (475)	15 (14)
	S-OW	14,000 (5700)	175 (159)
		37,000 (15 000)	860 (780)

** Identified deposit areas within Point Pelee National Park, the towns of Leamington, Kingsville and Essex and the village of Wheatley have been omitted on all tables.*

N.B. Minor variations in tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.

1 No.	2 Ministry Of Transport-ation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
Gosfield South Township							
1	E2-39	Township of Mersea	24	5	36.7 (14.9)	10-20 (3-6)	<25
2	E2-22	538269 Ontario Limited	24	5	29.77 (12.05)	25-70 (8-21)	<25
3	E2-57	Erie Sand and Gravel Limited	Pt. 23&24	4	133.85 (54.17)	5-10 (1.5-3)	20-30
4	E2-54	Erie Sand and Gravel Limited	23	4 ED	12.1 (4.9)	6-10 (2-3)	30-40 variable
5	E2-53	County of Essex	Pt.22	4	10.0 (4.1)	20 (6)	overgrown
6	-	Township of Gosfield South	Pt.11 &12	3	7.0 (2.8)	15-20 (5-6)	<20 overgrown
7	E2-3	County of Essex	Pt.11 &12	3	70.7 (28.6)	15-30 (5-9)	20-30
8	E2-4	Spinks Gravel Limited	11&12	3	71.0 (28.7)	10-20 (3-6)	<25
			12	2		10 (3)	<25 overgrown
9	-	Township of Gosfield South	Pt.8 &9	3 ED	8.2 (3.3)	unopened property	-
10	-	Township of Gosfield North	13	2	7.6 (3.1)	15-20 (5-6)	<25
11	-	Kennette Contracting Company Limited	Pt.13	2	46.8 (18.9)	unopened property	-
Total for Gosfield South Township					433.72 (175.52)		
Mersea Township							
12	E2-55	Kennette Contracting Company Limited	Pt.1	4	16.46 (6.7)	5-8 (1.5-2)	<20 water filled
13	-	Kennette Contracting Company Limited	1	4	16.014 (6.481)	6-8 (2)	<20 largely rehabilitated
14	E2-29	Sterling Acre Farms Limited	Pt.1	3	15.89 (6.43)	water filled property	20-30
15	E2-29	Sterling Acre Farms Limited	1	3	19.15 (7.75)	5-10 (1.5-3)	20-30

TABLE 2. SAND AND GRAVEL PITS, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.

1 No.	2 Ministry Of Transport-ation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
16	-	Erie Sand and Gravel Limited	Pt.1	2	4.5 (1.8)	8-10 (2-3)	10-30 variable
17	E2-20	Erie Sand and Gravel Limited	Pt.1 &2	2	51.9 (21.0)	dredging operation 15-20 (5-6)	10-30 water filled variable
18	-	Erie Sand and Gravel Limited	Pt.2	2	5 (1.5)	6-9 (2-3)	10-30 water filled
19	-	Erie Sand and Gravel Limited	Pt.2	2	27.45 (11.11)	15 (5)	10-30 water filled
20	E2-14	Erie Sand and Gravel Limited	1&2	2	38.7 (15.7)	dredging operation 15-30 (5-9)	10-30 largely water filled & overgrown variable
21	E2-32	Kennette Contracting Company Limited	Pt.1	2	82.6 (33.4)	20-40 (6-12)	<25 largely water filled
22	-	Kennette Contracting Company Limited	Pt.3	2	8.0 (3.2)	15-20 (5-6)	<20
23	-	Sterling Acre Farms Limited	Pt.6	R.P. 402	6.9 (2.8)	8-10 (2-3)	rehabilitated
24	-	Wilmast Developments Limited	3,4,5 &6	R.P. 402	95.33 (38.58)	10-20 (3-6)	<20 partially rehabilitated
			1,2,3, &4	R.P. 440			
25	E2-41	Leamington Sand and Gravel Limited	Pt.6,11 &12	R.P. 402	36.0 (14.6)	5-15 (1.5-5)	partially rehabilitated <35
			Pt.5	I			
26	E2-50	Marentette Brothers Limited	Pt.18	A	23.0 (9.3)	8-9 (2-3) below water	water filled variable
Total for Mersea Township					446.89 (180.85)		
TOTAL FOR REPORT AREA					880.61 (356.38)		

TABLE 2. SAND AND GRAVEL PITS, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.

1 No.	2 Ministry Of Transport-ation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
UNLICENCED PITS*							
Gosfield North Township							
27	-	Unknown	Pt.272	S.T.R.	-	10-12 (3-4)	overgrown & water filled
28	-	Unknown	Pt.267	N.T.R.	-	5 (1.5)	<20 overgrown & water filled
29	E2-18	Harris	Pt.24 &25	7	-	10-15 (3-5)	sand source
30	E2-24	P.J.Raunch	Pt.24 &25	7	-	10-15 (3-5)	sand source
Gosfield South Township							
31	-	Unknown	Pt.12	5	-	water filled	clay source
32	-	Unknown	Pt.12	5	-	<5 (<1.5)	clay source
33	-	Unknown	Pt.12	4	-	water filled	clay source
34	-	Unknown	Pt.K	3	-	water filled	clay source
35	-	Unknown	Pt.9	FSWD	-	<5 (<1.5)	<10 overgrown
36	E2-08	Tri-County Pit. #2	Pt.19	4	-	5-10 (1.5-3)	10-20
37	E2-31	Colasanti Farms Limited	Pt.9	3	-	5-10 (1.5-3)	<20 water filled
38	E2-15 E2-53	G. Whaley County of Essex	Pt.22 &23	4	-	15-20 (5-6)	overgrown & water filled
39	E2-5	Harry Fisher	Pt.11	3	-	5-10 (1.5-3)	<20 rehabilitated
40	E2-30	Leamington Sand and Gravel	Pt.11 &12	3	-	5-10 (1.5-3)	<25 overgrown & water filled
41	E2-11	Tuma	Pt.11	3	-	5-15 (1.5-5)	<15 overgrown & water filled
42	E2-25	Gosfield Township	Pt.12	2	-	15-20 (5-6)	overgrown
Mersea Township							
43	E2-16	Leamington Sand and Gravel (Bradley)	Pt.2	4	-	7-10 (2-3)	<30 partially water filled & overgrown
44	E2-38	Albert Quick	Pt.1	2	-	10-15 (3-5)	<20 overgrown & partially water filled

* *Abandoned pits or wayside pits operating on demand under authority of a permit.*

TABLE 2. SAND AND GRAVEL PITS, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.

1 No.	2 Ministry Of Transport-ation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
45	E2-6	Keystone Construction Company	Pt.2&3	2	-	20 (6)	overgrown & waterfilled
46	E2-27	Kennette Construction Company	Pt.3	1	-	20-30 (6-9)	overgrown
47	E2-1 E2-21	Dean Kennette Construction Company	Pt.5	1	-	5-10 (1.5-3)	<10 overgrown

TABLE 3. SELECTED SAND AND GRAVEL RESOURCES AREAS, MERSEA, GOSFIELD NORTH AND GOSFIELD SOUTH TOWNSHIPS.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions Of Tons (Tonnes)
1	3900 (1580)	1560 (630)	140 (57)	2200 (890)	15 (5)	82 (74)
2	1980 (800)	480 (194)	10 (4)	1490 (600)	15 (5)	56 (51)
	5900 (2390)	2040 (820)	150 (61)	3700 (1500)		138 (125)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, MERSEA, GOSFIELD NORTH AND GOSFIELD SOUTH TOWNSHIPS.

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
25–50 (8–15)	Dundee Formation	60 (18)	145 (59)	31 (28)
25–50 (8–15)	Detroit River Group Lucas Formation	60 (18)	445 (180)	96 (87)
25–50 (8–15)	Detroit River Group Amherstburg Formation	60 (18)	5 (2)	1 (1)
			600 (243)	128 (116)

TABLE 5. QUARRIES, MERSEA, GOSFIELD NORTH AND GOSFIELD SOUTH TOWNSHIPS.

1 NO.	2 MINISTRY OF TRANSPORTATION NO.	3 OWNER/ OPERATOR	4 LOT	5 CON	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

- NONE -

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, MERSEA, GOSFIELD NORTH AND GOSFIELD SOUTH TOWNSHIPS.

1 Deposit No.	2 Depth of Overburden Feet (Metres)	3 Unlicenced Area Acres (Hectares)	4 Cultural Setbacks Acres (Hectares)	5 Extracted Area Acres (Hectares)	6 Available Area Acres (Hectares)	7 Estimated Workable Thickness Feet (Metres)	8 Available Resources Millions Of Tons (Tonnes)

- NONE -

TABLE 7. SUMMARY OF TEST HOLE DATA, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.

Test Hole Number: GM-TH-1

Location: Lots 22 & 23, Concession 5, Gosfield South Township

Elevation: Approximately 650 feet (198 m) to 675 feet (206 m) a.s.l.

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0-4.0 (0-1.2)	silty sand
4.0-13.0 (1.2-4.0)	silty sand till massive in waterlain layers, red shale fragments water table encountered at 10 feet (3 m)
13.0-20.0 (4.0-6.1)	silty sand
20.0-37.0 (6.1-11.3)	clean medium to coarse sand test hole terminated at 37.0 feet (11.3 m)

Test Hole Number: GM-TH-2

Location: Lot 22 & 23, Concession 5, Gosfield South Township

Elevation: Approximately 700 feet (213 m) a.s.l.

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0-5.5 (0-1.7)	clean sand <10 percent fine gravel
5.5-6.5 (1.7-2.0)	clay till
6.5-15.0 (2-4.6)	clean gritty coarse sand
15.0-52.0 (4.6-15.8)	clean medium to coarse sand test hole terminated at 52.0 feet (15.8 m)

Test Hole Number: GM-TH-3

Location: Lot 24, Concession 5, Gosfield South Township, (drilled in northwest corner of Licenced Pit No. 2).

Elevation: Approximately 700 feet (213 m) a.s.l. (test hole completed in lowest floor of pit).

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0-11.0 (0-3.4)	gravelly sand
11.0-22.0 (3.4-6.7)	coarse gritty sand
22.0-24.5 (6.7-7.5)	hard clay
24.5-29.0 (7.5-8.8)	gritty coarse silty sand
29.0-33.0 (8.8-10.0)	finely laminated lacustrine clay
33.0-36.5 (10.0-11.1)	gritty coarse sand
36.5-37.0 (11.1-11.3)	6 inch (15.2 cm) layer of well stratified clay
37.0-50.0 (11.3-15.2)	gritty coarse sand with occasional fine layers of clay
50.0-80.0 (15.2-24.4)	gritty coarse sand terminated hole at 80.0 feet (24.4 m)

Test Hole Number: GM-TH-4

Location: Lots 23 & 24, Concession 4, Gosfield South Township, (drilled in floor of Licenced Pit No.3)

Elevation: Approximately 700 feet (213 m) to 725 feet (221 m) a.s.l.

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0-15.0 (0-4.6)	medium sand
15.0-52.0 (4.6-15.8)	massive sandy silt till terminated hole at 52.0 feet (15.8 m)

Test Hole Number: GM-TH-5

Location: Lot 11 & 12, Concession 3, Gosfield South Township, (drilled in floor of Licenced Pit No. 7)

Elevation: Approximately 725 feet (221 m) to 750 feet (229 m) a.s.l.

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0-11.5 (0-3.5)	gravelly sand
11.5-21.0 (3.5-6.4)	sandy silt till
21.0-31.0 (6.4-6.7)	faint layer of sandy silt
22.0-31.0 (6.7-9.4)	sandy silt till
31.0-32.0 (9.4-9.8)	clean medium sand
32.0-42.0 (9.8-12.8)	very stoney, over consolidated sand till test hole terminated at 42.0 feet (12.8 m).

TABLE 7. SUMMARY OF TEST HOLE DATA, MERSEA, GOSFIELD NORTH & GOSFIELD SOUTH TOWNSHIPS.

Test Hole Number: GM-TH-6

Location: Lot 1, Concession 4, Mersea Township, (drilled in floor of Licenced Pit no.12)

Elevation: Approximately 675 feet (206 m) to 700 feet (213 m) a.s.l.

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0–13.0 (0–4.0)	gravelly sand
13.0–19.5 (4.0–5.9)	fine sand
19.5–20.8 (5.9–6.3)	waterlain till and medium sand
20.8–41.0 (6.3–12.5)	massive gritty silt till
41.0–57.0 (12.5–17.4)	medium sand with grits test hole terminated at 57.0 feet (17.4 m)

Test Hole Number: GM-TH-7

Location: Lot 1 & 2, Concession 2, Mersea Township, (drilled in floor of Licenced Pit No. 21)

Elevation: Approximately 700 feet (213 m) a.s.l.

Source: E.V. Sado, Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey.

Depth Feet (metres)	Description
0–3.0 (0–0.9)	fine gravelly sand water table encountered at 2 feet (0.6 m)
3.0–4.5 (0.9–1.4)	silt till
4.5–21.0 (1.4–6.4)	fine to coarse gravelly sand
21.0–53.0 (6.4–16.2)	massive gritty silty sand till
53.0–62.0 (16.2–18.9)	very consolidated and stony silty sand till test hole terminated at 62.0 feet (18.9 m)

Test Hole Number: GM-TH-8

Location: Lot 8, Concession 1, Gosfield South Township

Elevation: Approximately 570 feet (174 m) a.s.l.

Source: From files of Petroleum Resources Section, M.N.R.

Depth Feet (metres)	Description
0–45 (0–14)	drift
45–275 (14–84)	Detroit River Group
275–435 (84–133)	Bass Islands Formation
435–905 (133–276)	Salina Formation test hole continued to 914 feet (279 m), abandoned.

TABLE 8. SUMMARY OF GEOPHYSICS DATA, MERSEA, GOSFIELD NORTH AND GOSFIELD SOUTH TOWNSHIPS.

Line Number: GM-GT-1

Line Direction: 90 degrees

Method: Hammer Seismic

Location: Lot 23, Concession 4, Gosfield South Township (completed on floor of Licenced Pits Nos. 3 and 4)

Elevation: Approximately 700 feet (213 m) to 725 feet (221 m) a.s.l.

Geology: Glaciolacustrine beach sediment

Seismic Data:

Number of Layers: 2

Layer Velocitics: V_1 = 1100 feet/sec (335 m/sec.)
V_2 = 5300 feet/sec (1615 m/sec.)

Layer Thickness: 8 feet (2.4 m).

Interpretation:

Layer 1:	Approximately 8 feet (2.4 m) of fine aggregate.
Layer 2:	Till possibly encountered and velocities increased to 5300 feet/sec. (1615 m/sec.) (water well data in this immediate area indicates the presence of clay underlying the beach sediments).

TABLE 9. AGGREGATE QUALITY TEST DATA, MERSEA, GOSFIELD NORTH AND GOSFIELD SOUTH TOWNSHIPS.

- NONE -

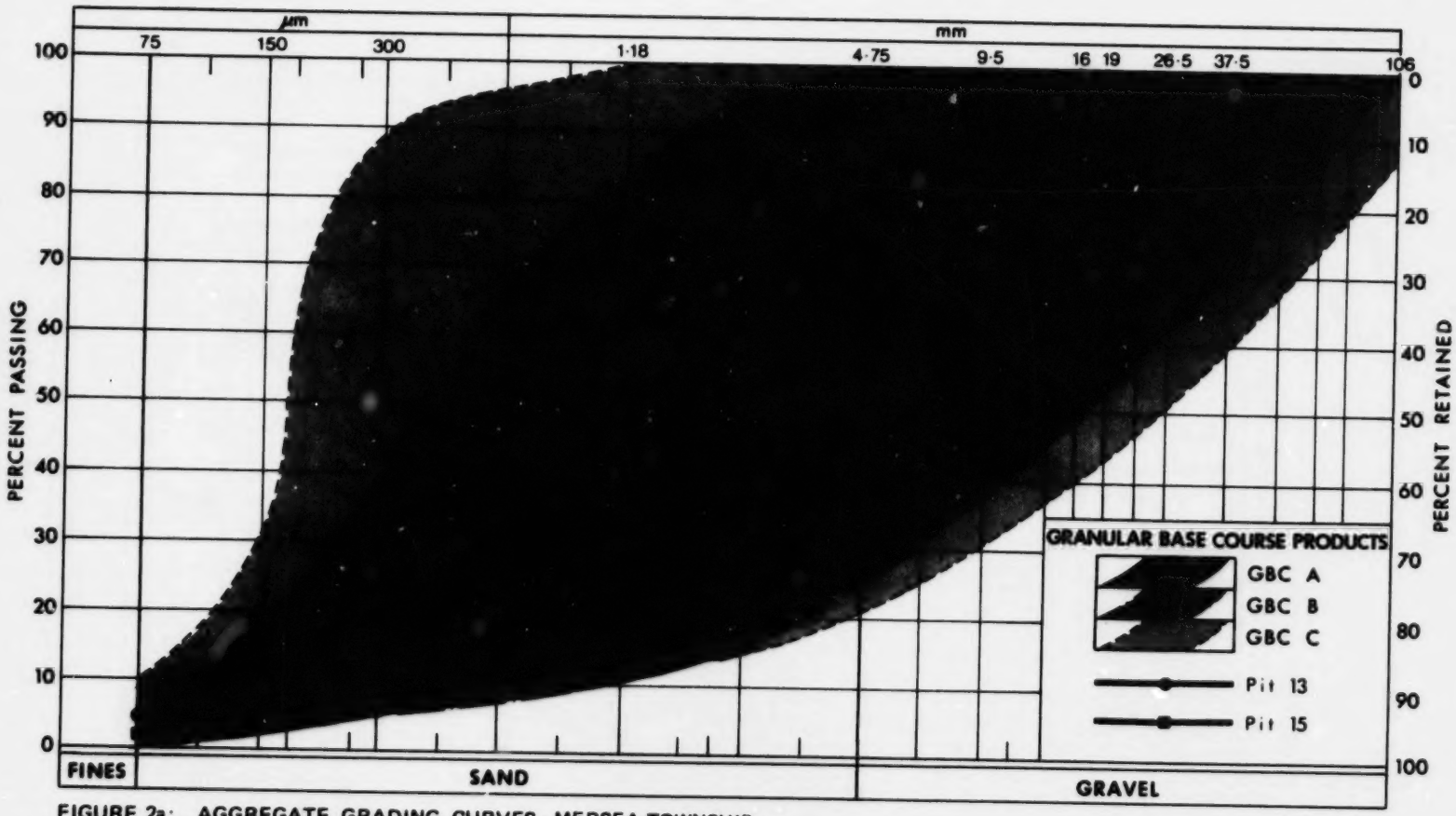


FIGURE 2a: AGGREGATE GRADING CURVES, MERSEA TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

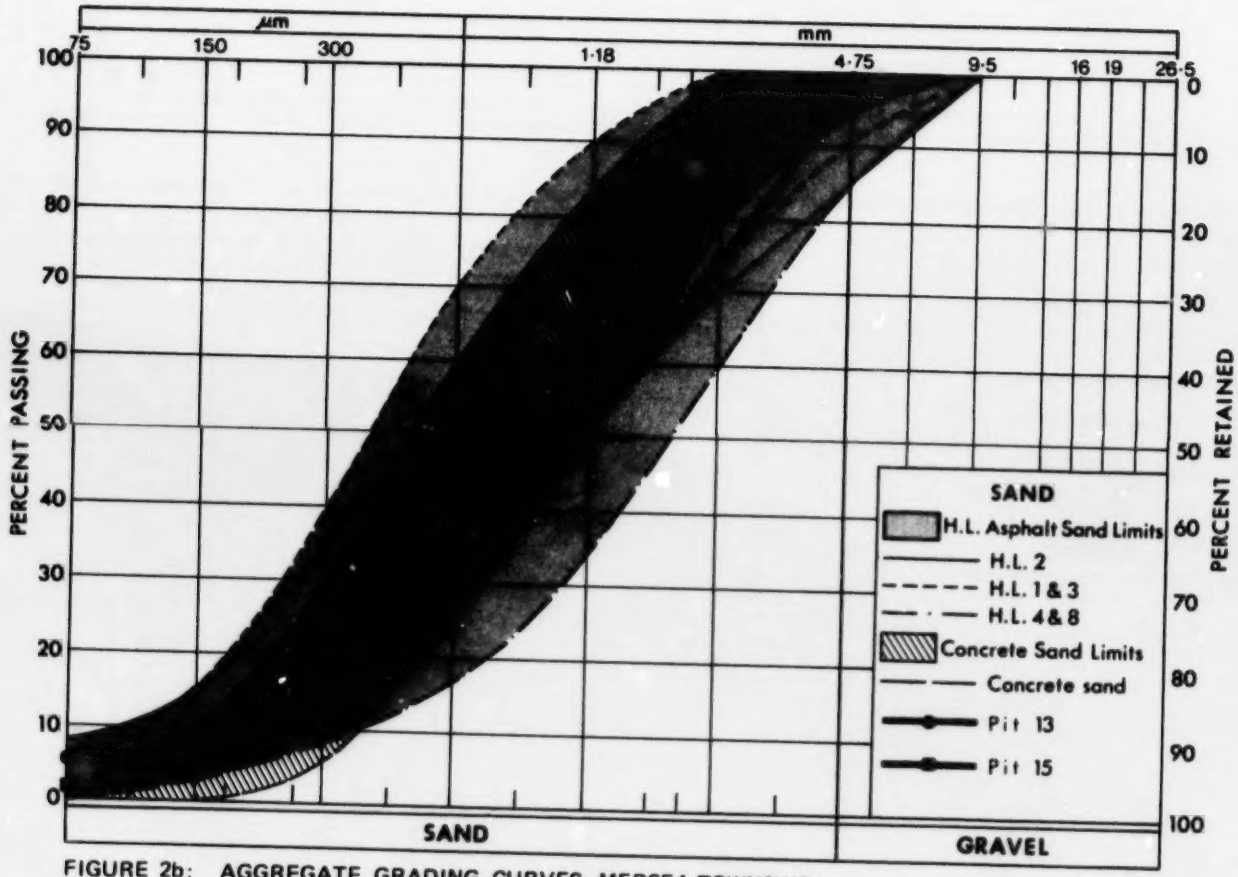


FIGURE 2b: AGGREGATE GRADING CURVES, MERSEA TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

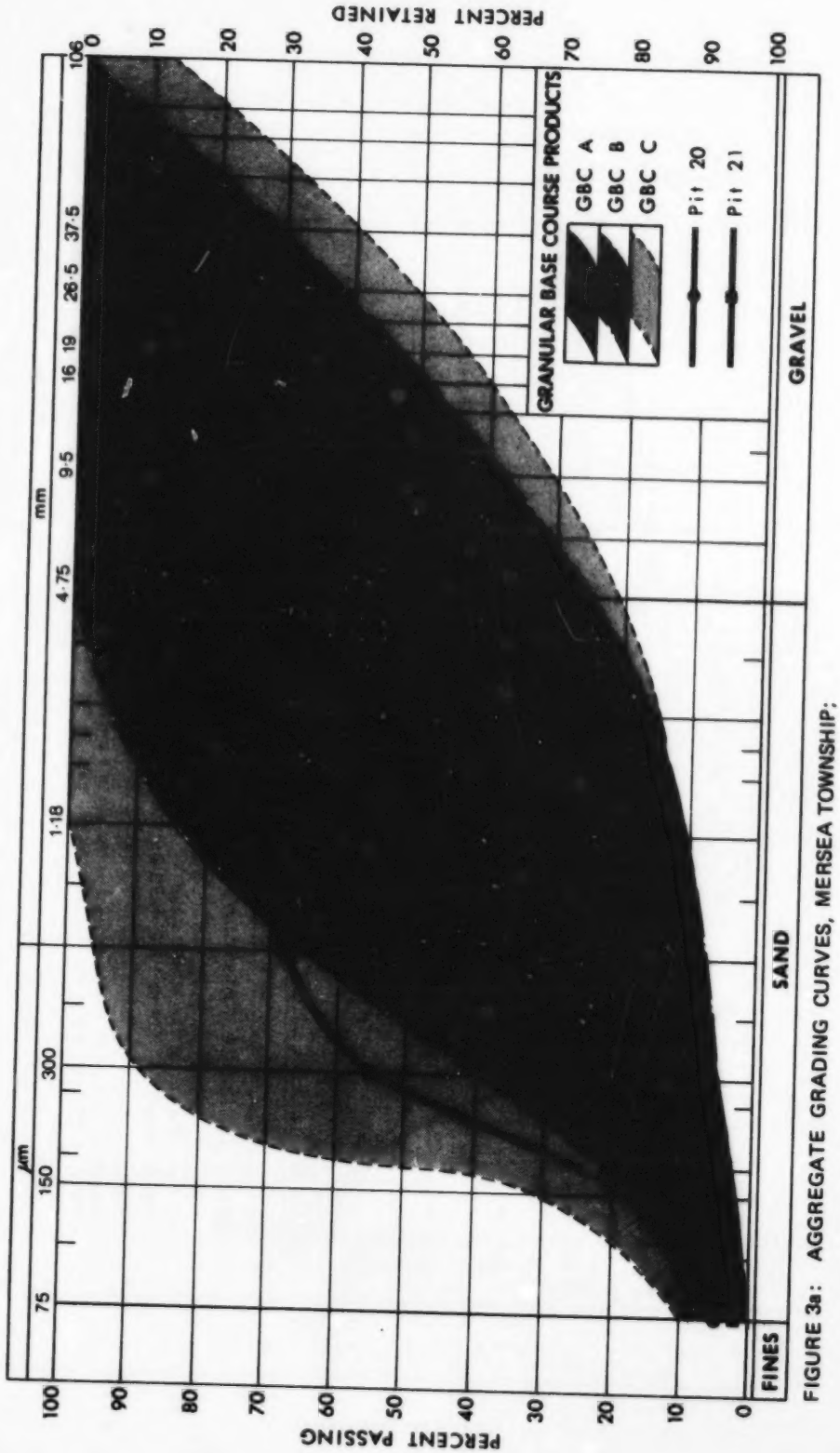


FIGURE 3a: AGGREGATE GRADING CURVES, MERSEA TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

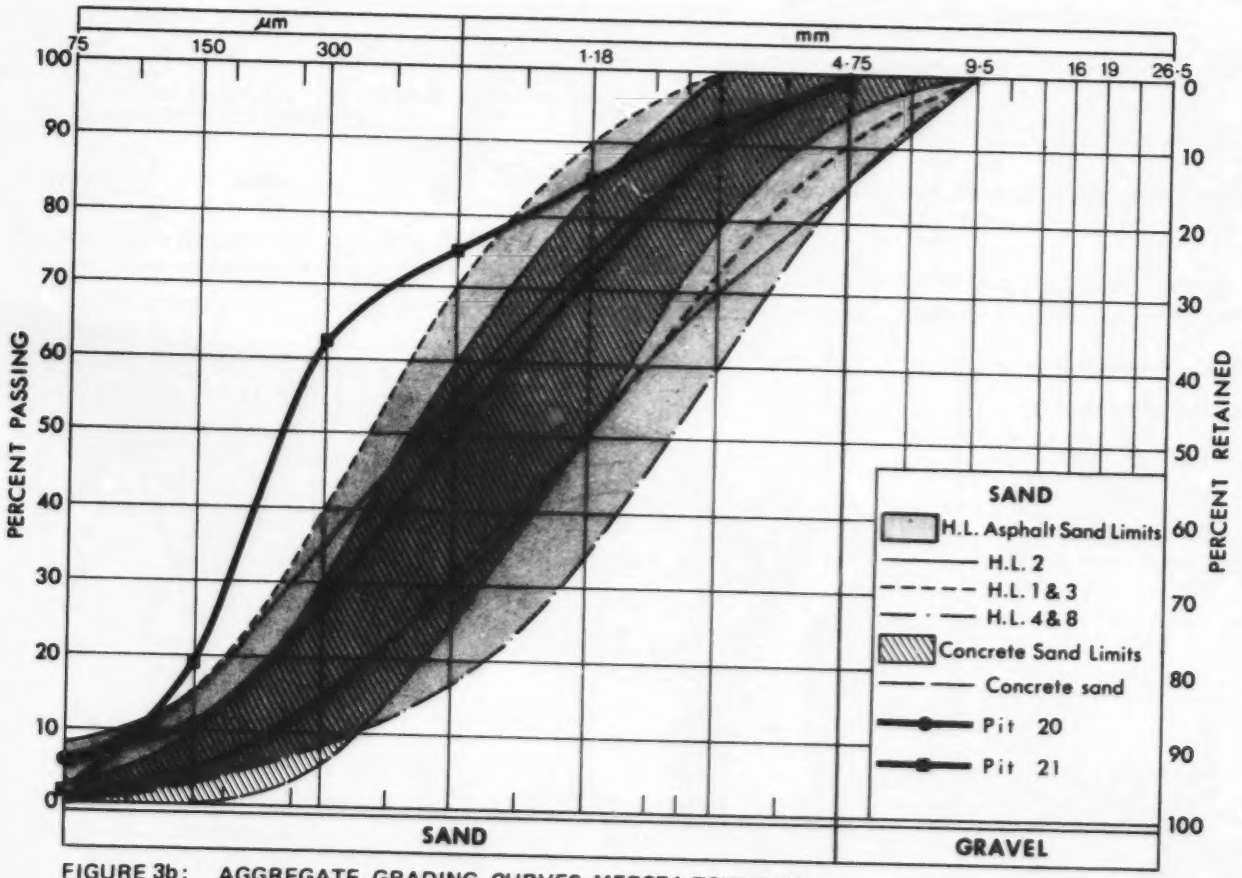


FIGURE 3b: AGGREGATE GRADING CURVES, MERSEA TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

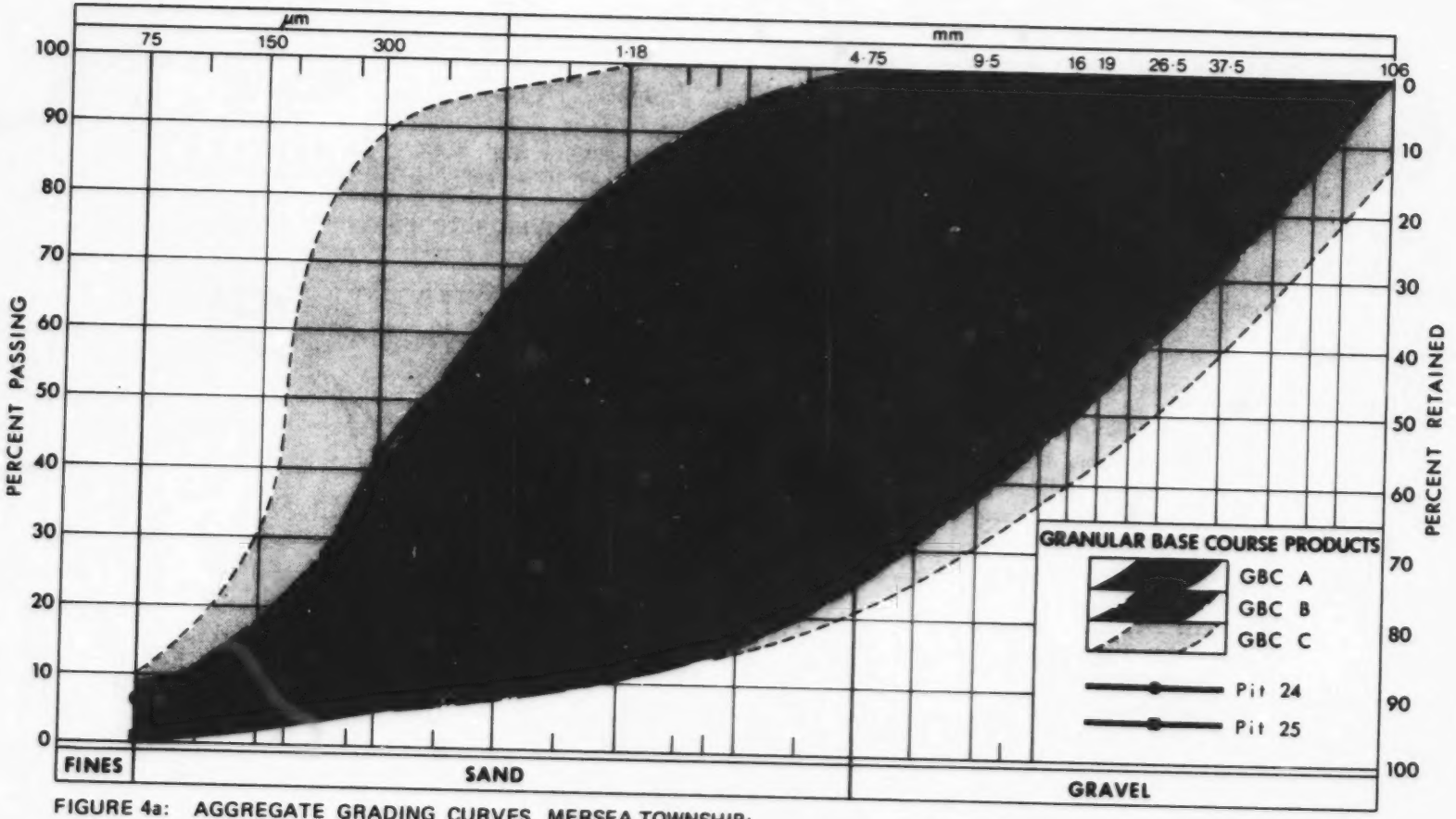


FIGURE 4a: AGGREGATE GRADING CURVES, MERSEA TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

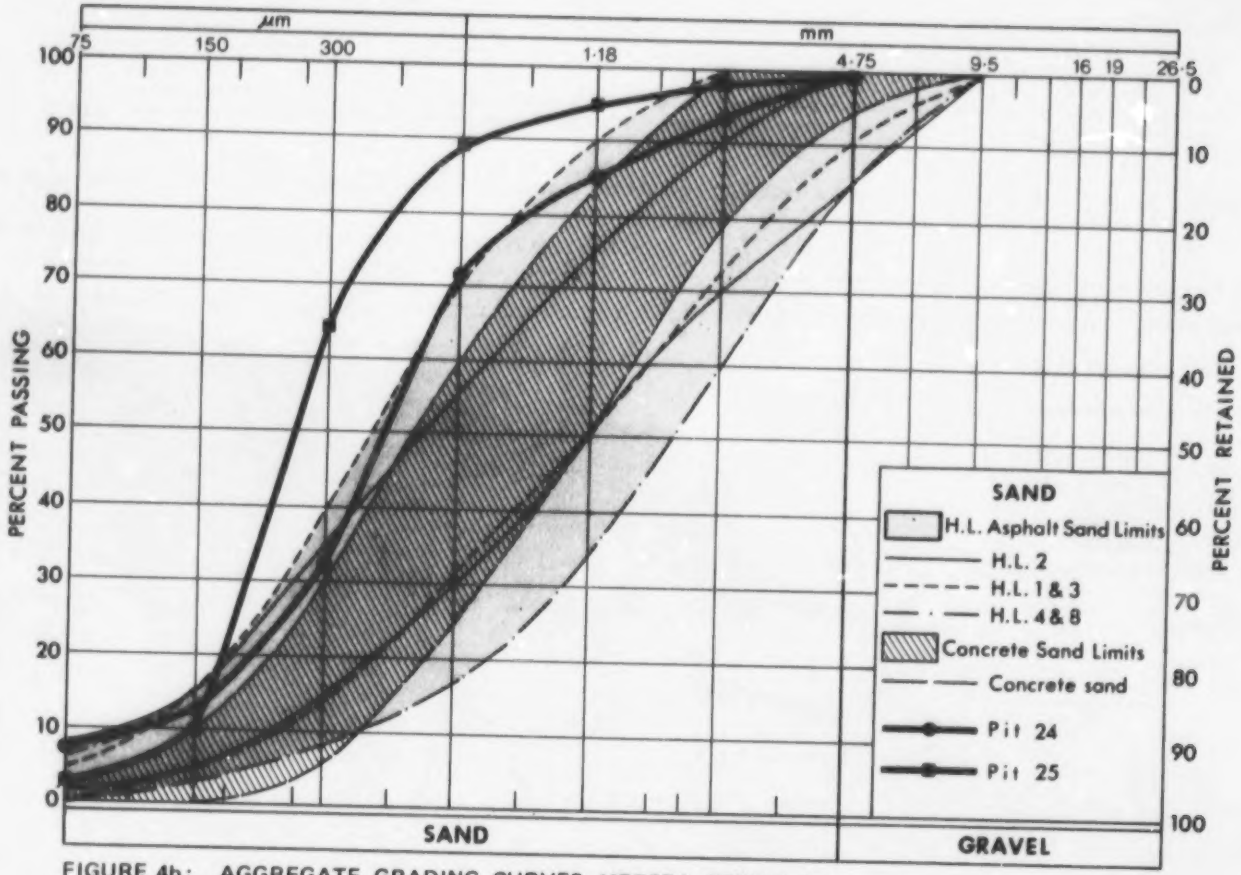


FIGURE 4b: AGGREGATE GRADING CURVES, MERSEA TOWNSHIP:

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

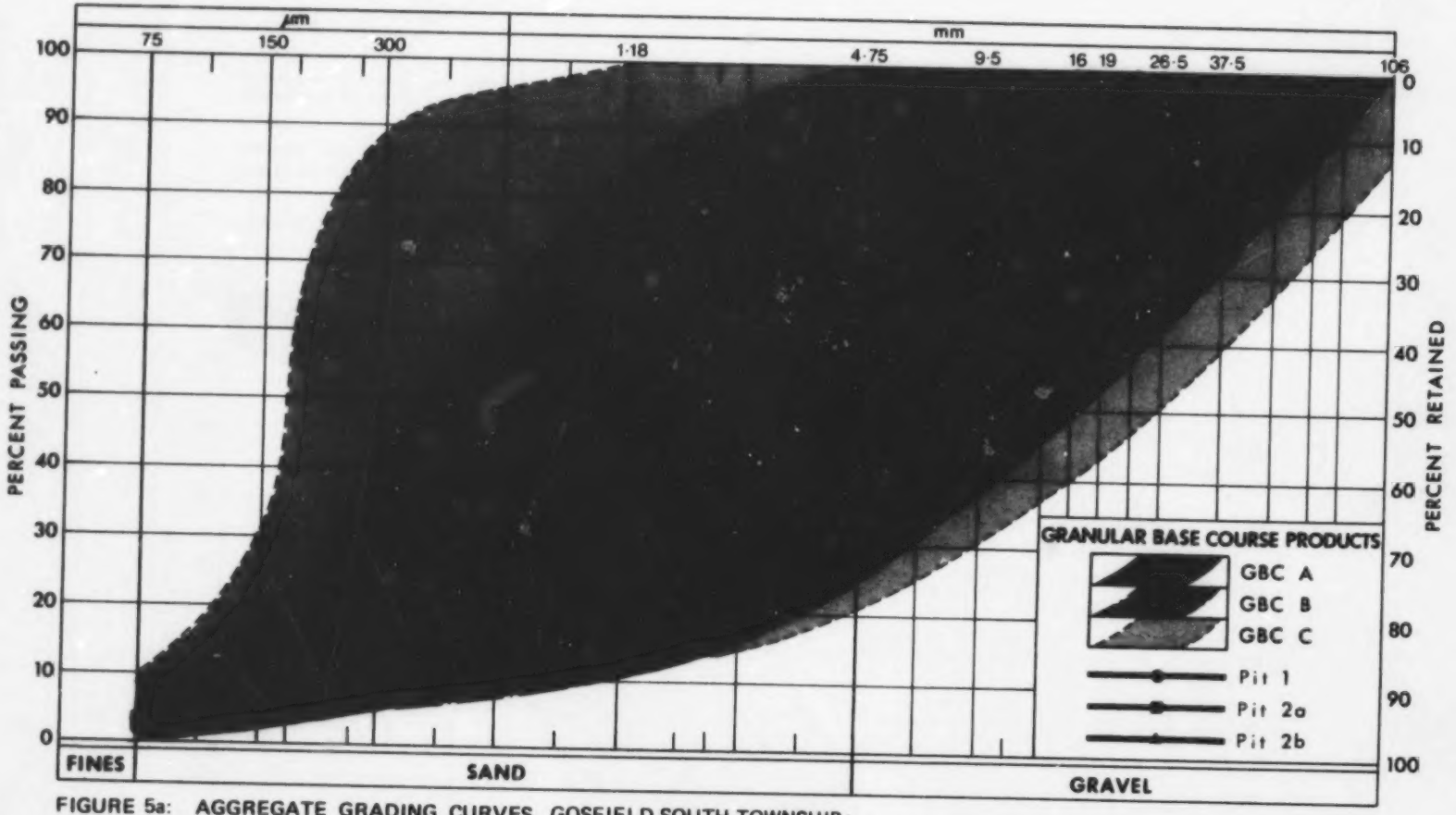


FIGURE 5a: AGGREGATE GRADING CURVES, GOSFIELD SOUTH TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

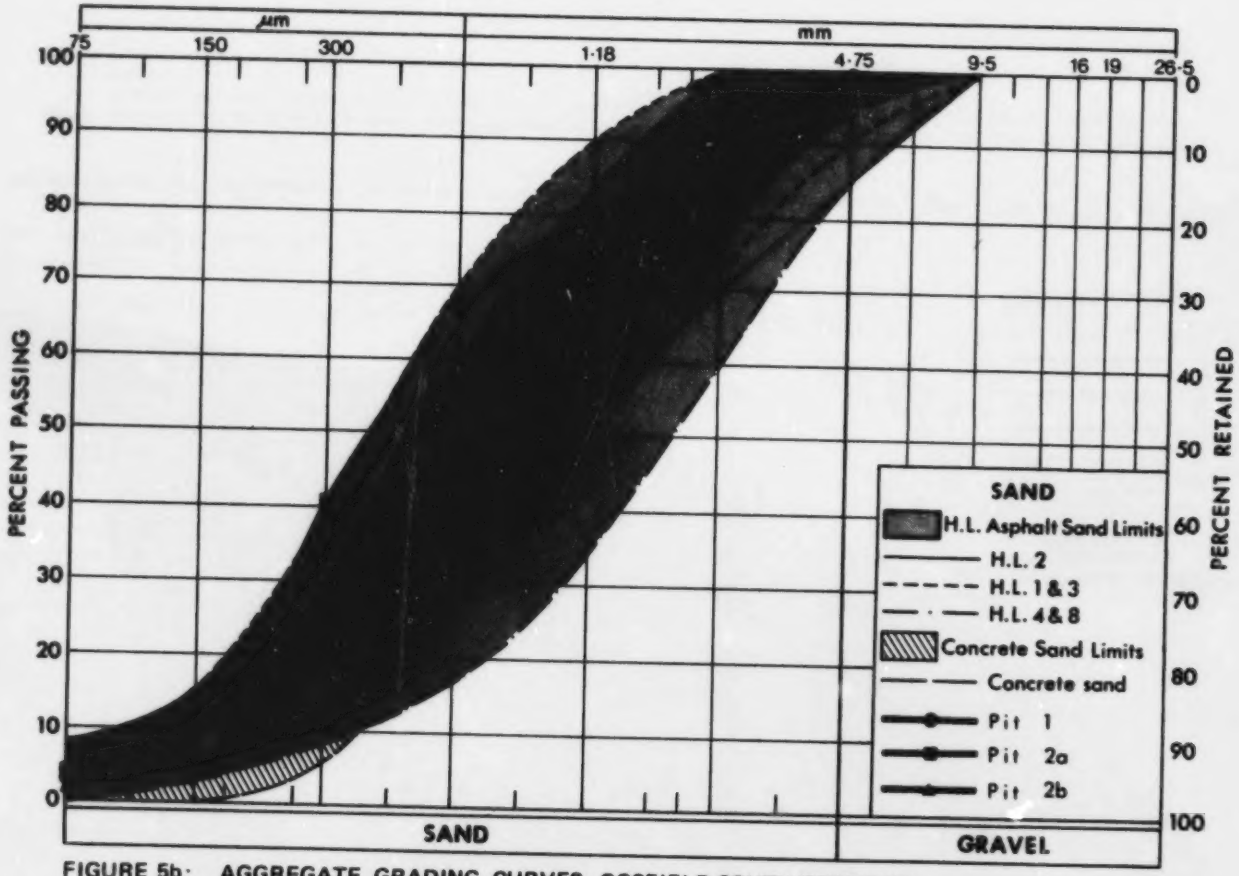


FIGURE 5b: AGGREGATE GRADING CURVES, GOSFIELD SOUTH TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

FIGURE 6a: AGGREGATE GRADING CURVES, GOSFIELD SOUTH TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

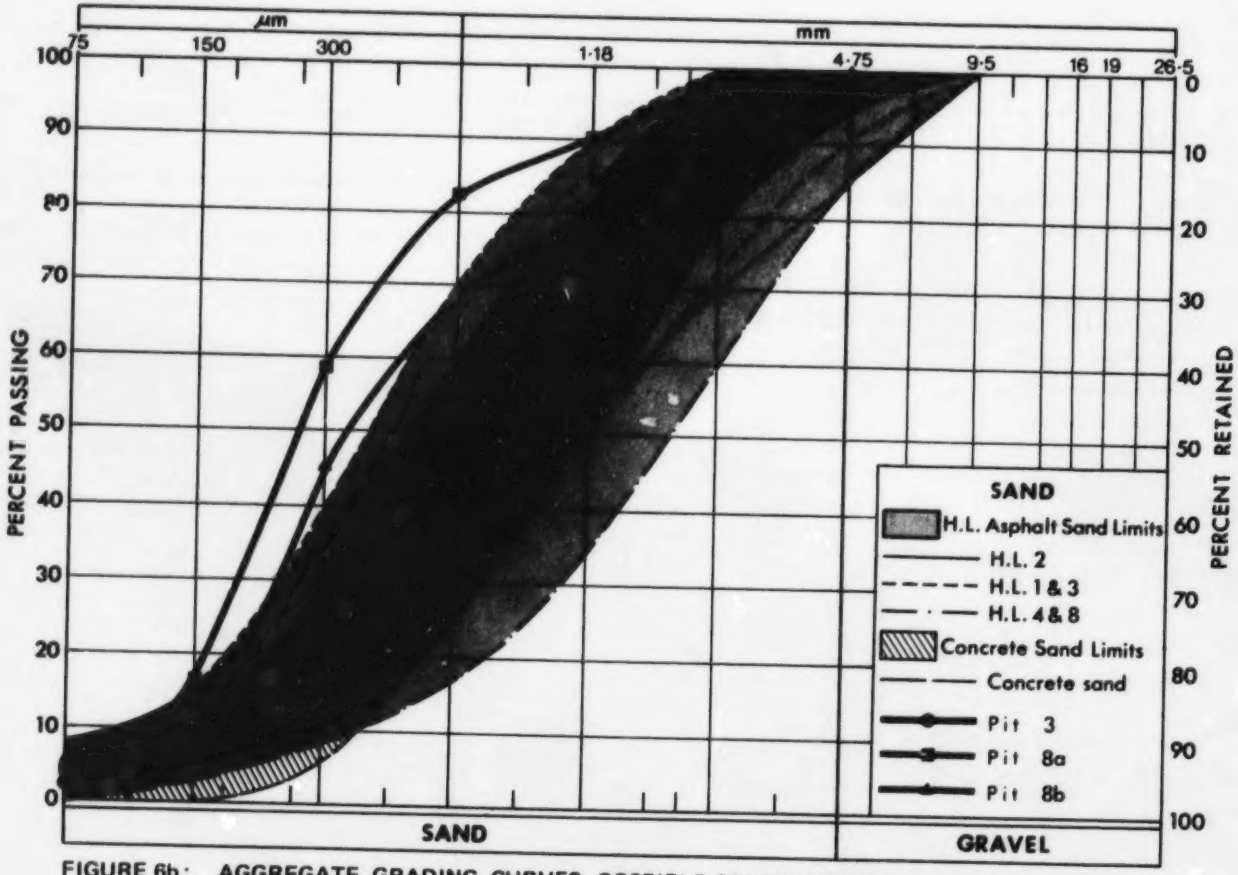


FIGURE 6b: AGGREGATE GRADING CURVES, GOSFIELD SOUTH TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

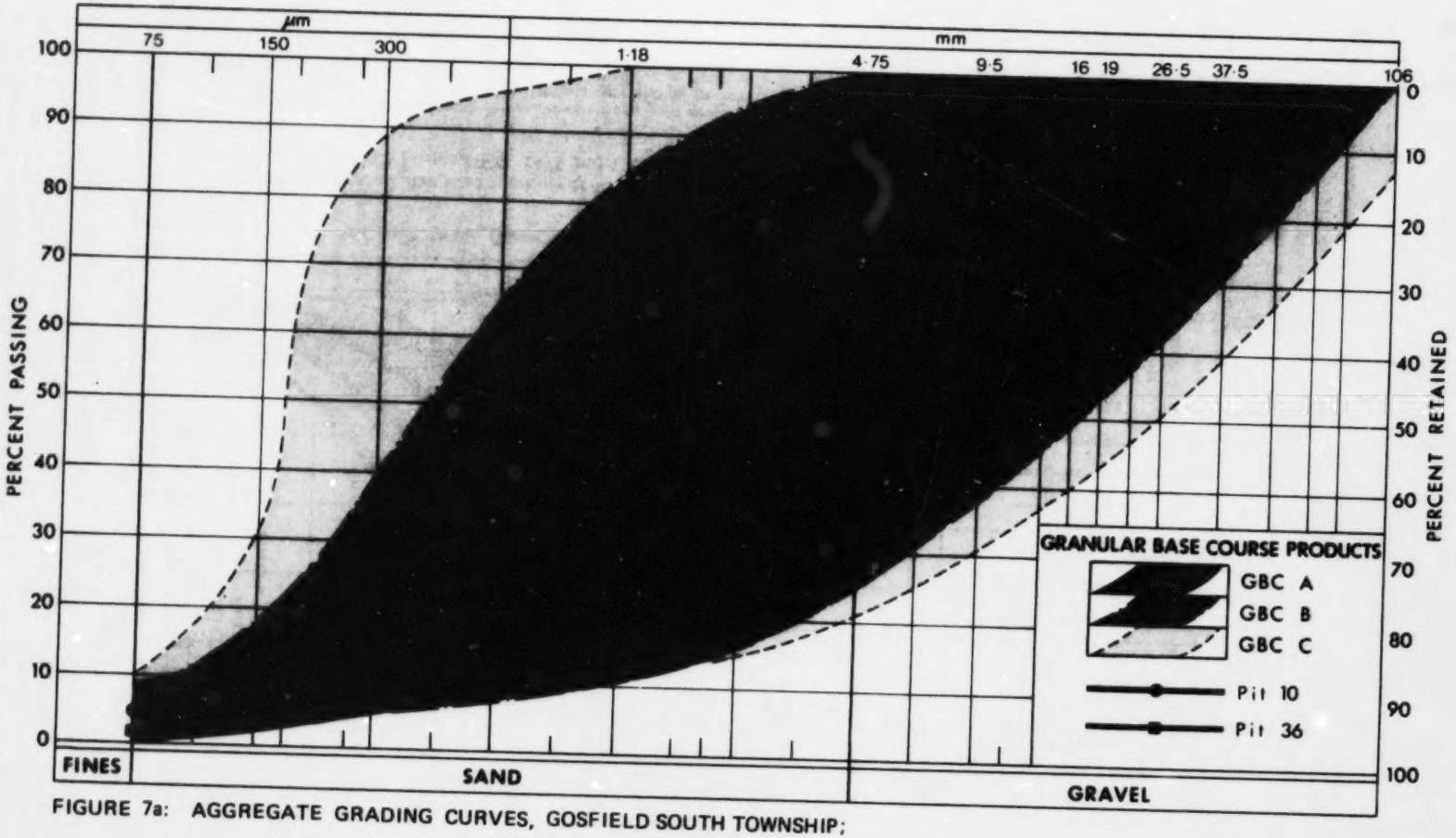


FIGURE 7a: AGGREGATE GRADING CURVES, GOSFIELD SOUTH TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

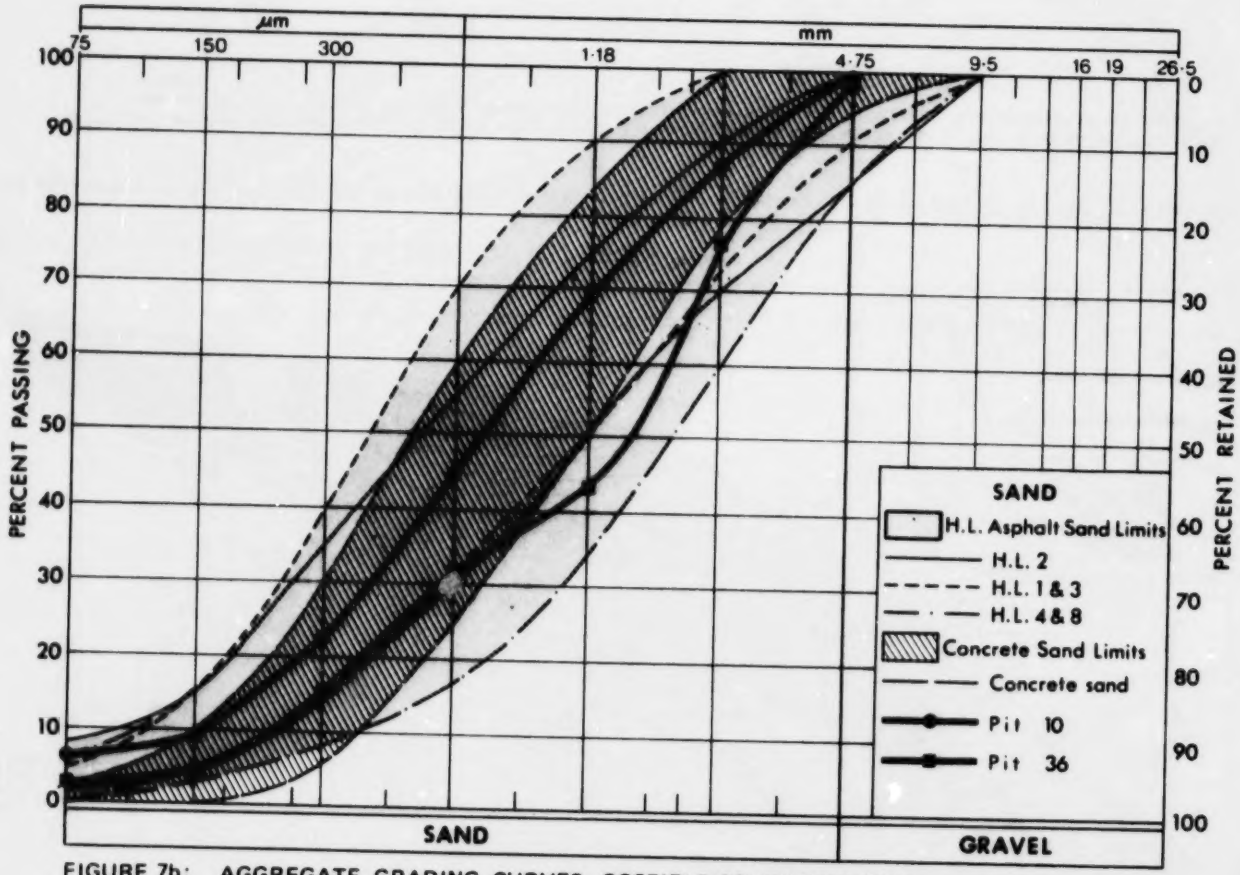


FIGURE 7b: AGGREGATE GRADING CURVES, GOSFIELD SOUTH TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

References

Association of Professional Engineers of Ontario

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various–sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desireable.

Alkali–aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali–aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali–reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g. "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand–sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non–durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road–building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue–like projection from the margin of the main mass of an ice cap or ice sheet.

During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75–200 mm
Coarse Gravel	26.5–75 mm
Fine Gravel	4.75–26.5 mm
Coarse Sand	2–4.75 mm
Medium Sand	0.425–2 mm
Fine Sand	0.075–0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit–run or other unprocessed aggregate.

Hot–laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35 percent indicate potentially satisfactory performance for most concrete and aspphalt uses. Values of more than 45 percent indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15 percent indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine–grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of ab-

sorbed solutions. This may seriously impair the performance of road–building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice–Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice–contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine–grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt– and clay–sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice–Contact Stratified Drift (IC): This designation may include deposits from several ice–contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse–grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As

these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi–sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt– and clay–sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand–sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse–grained materials such as a stony till, and low when developed from fine–grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near–ice and ice–contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate–poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice–contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre–existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54–68, AAV = 4–15, $MgSO_4$ = 9–32, LA = 44–90, Absn = 1.6–2.6, BRD = 2.38–2.50, PN (Asphalt & Concrete) = 130–140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate. Suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55–60, AAV = 4–6, $MgSO_4$ = 1–17, LA = 15–38, Absn = 0.5–0.9, BRD = 2.61–2.65, PN (Asphalt & Concrete) = 110–150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaley interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47–48, AAV = 7–8, $MgSO_4$ = 1–4, LA = 18–23, Absn = 0.7–0.9, BRD = 2.74–2.78, PN (Asphalt & Concrete) = 105–120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58–63, AAV = 10–11, $MgSO_4$ = 12–40, LA = 25–28, Absn = 1.8–1.9, BRD = 2.55–2.62, PN (Asphalt & Concrete) = 122–440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario – the basal unit of the Ottawa Group; central Ontario – overlain by the Simcoe Group. COMPOSITION: in eastern Ontario – silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario – conglomerates, sandstones, and shales. THICKNESS: eastern Ontario – 7 to 10 feet (2 to 3 m); central Ontario – 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: Part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin–bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin– to thick–bedded, interbedded, grey argillaceous limestone and buff to green dolostone whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: Quarried in the Lake Simcoe, Kingston, Ottawa, and Cornwall areas for crushed stone. Rock from certain layers in eastern and central Ontario has proven to be alkali–reactive when used in Portland cement concrete (alkali–carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41–49, AAV = 8–12, $MgSO_4$ = 3–13, LA = 18–28, Absn = 0.3–0.9, BRD = 2.68–2.73, PN (Asphalt & Concrete) = 100–153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: Part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin–bedded fine–crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: Quarried at Brechin, Marysville, and in the Ottawa area for crushed stone. Generally suitable for use as granular base course aggregate. Rock from certain layers has been found to be alkali–reactive when used in Portland cement concrete (alkali–silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47–51, AAV = 14–23, $MgSO_4$ = 1–40, LA = 18–32, Absn = 0.3–2.4, BRD = 2.5–2.69, PN (Asphalt & Concrete) = 100–320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: Quarried at Picton and Bath for use in cement manufacture. Quarried for aggregate in Mara Township, Simcoe County and in the Belleville–Kingston area. May be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43–44, AAV = 9–13, $MgSO_4$ = 4–45, LA = 22–29, Absn = 0.4–2.1, BRD = 2.59–2.70, PN (Asphalt & Concrete) = 120–255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: Part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: eastern Ontario – the lower member is interbedded, very fine– to coarse–crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine– to fine–crystalline, petroliferous limestone; central Ontario – Collingwood Member is a black, calcareous shale whereas the lower member is a very fine– to coarse–crystalline, thin–bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: eastern Ontario – lower member is used extensively for aggregate production; central Ontario – quarried at Picton, Ogden Point and Bowmanville for cement. May be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2–47, LA = 20–28, Absn = 0.4–1.3, BRD = 2.64–2.70, PN (Asphalt & Concrete) = 110–215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario – Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario – Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: Blue Mountain Formation blue–grey, noncalcareous shales; Billings Formation – dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation – 140 to 200 feet (43 to 61 m); Billings Formation – 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: central Ontario – Georgian Bay Formation composed of interbedded limestone and shale; eastern Ontario – Carlsbad Formation composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation – 300 to 560 feet (91 to 170 m); Carlsbad Formation – 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation – used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate. Carlsbad Formation – used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: Red, thin– to thick–bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: There are several large quarries developed in the Queenston Formation in the Toronto–Hamilton region and one at Russell, near Ottawa. All extract shale for brick manufacturing. The Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Penninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium– to coarse–grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 – 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin–bedded, blue–grey to buff–brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: No data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile. Lack of suitability exposures has limited use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick–bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 – 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION; dark–grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff–brown, micro– to medium–crystalline, thin– to medium–bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1–2, LA = 19–21, Absn = 0.6–0.7, BRD = 2.78–2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation – fine– to coarse–crystalline dolostone with high silica content; Reynales Forma-

tion – thin– to thick–bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation – 20 to 85 feet (6 to 26 m); Reynales Formation – 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse–crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15–60 feet (5–18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa Members. COMPOSITION: Lockport Formation is thin– to massive–bedded, fine– to medium–crystalline dolostone; Amabel Formation is thin bedded to massive, medium–crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36–49, AAV = 10–17, $MgSO_4$ = 2–6, LA = 25–32, Absn = 0.4–1.54, BRD = 2.61–2.81, PN (Asphalt & Concrete) = 100–105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: Exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: Micro–crystalline to medium–crystalline, thick–bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: Some areas appear soft and unsuitable for use in the production of load–bearing aggregate. This unit requires additional testing to fully establish its aggregate suitability. Main use is for dolomitic lime for cement manufacture. Quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; only rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: Gypsum mines at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium– to massive–bedded, micro–crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze–thaw durability. Has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46–49, AAV = 8–11, $MgSO_4$ = 4–19, LA = 14–23, Absn = 0.8–2.8, BRD = 2.61–2.78, PN (Asphalt & Concrete) = 102–120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick–to massive–bedded, coarse–grained, grey–yel-

low sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: Has been quarried for silica sand, building stone, and armour stone. May be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2–1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSITION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium– to coarse–grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. Material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48–53, AAV = 3–7, $MgSO_4$ = 3–18, LA = 15–22, Absn = 1.3–2.8, BRD = 2.50–2.70, PN (Asphalt & Concrete) = 102–290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium–bedded, fine– to coarse–grained, dark grey–brown or purplish–brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m) USES: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete. Has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1–6, LA = 16.8–22.4, Absn = 0.5–1.1, PN (Asphalt & Concrete) = 190–276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Penninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid–rich limestone and dolostone with grey chert nodules; Formosa Reef Limestone – high purity (calcium rich) limestone; Sylvania Sandstone Member – quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9–35, LA = 26–52, Absn = 1.1–6.4, BRD = 2.35–2.62, PN (Asphalt & Concrete) = 105–300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey–brown dolostone with bituminus laminations and minor chert; Anderdon Member consists of very high purity (calcium–rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: Most important source of high–purity limestone in Ontario. Used as calcium lime for metallurgical flux and for the manufacture of chemicals. Rock of lower purity is used for cement manufacture, agricultural lime and aggregate. Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46–47, AAV = 15–16, $MgSO_4$ = 2–60, LA = 22–47, Absn = 1.1–6.5, BRD = 2.35–2.40, PN (Asphalt & Concrete) = 110–160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: Fine– to medium–crystalline, brownish–grey, medium– to thick–bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: Quarried near Port Dover and on Pelee Island for crushed stone. Used at St. Marys as a raw material for portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1–28, LA = 22–46, Absn = 0.6–6.8, PN (Asphalt & Concrete) = 125–320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no out–crop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey–brown, very fine–grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: Part of the Hamilton Group. COMPOSITION: blue–grey, plastic, clay shale with

occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue–grey, fine–grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium– to coarse grained, grey–brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2–14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic–rich shale with minor interbeds of grey–green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine to medium grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses.

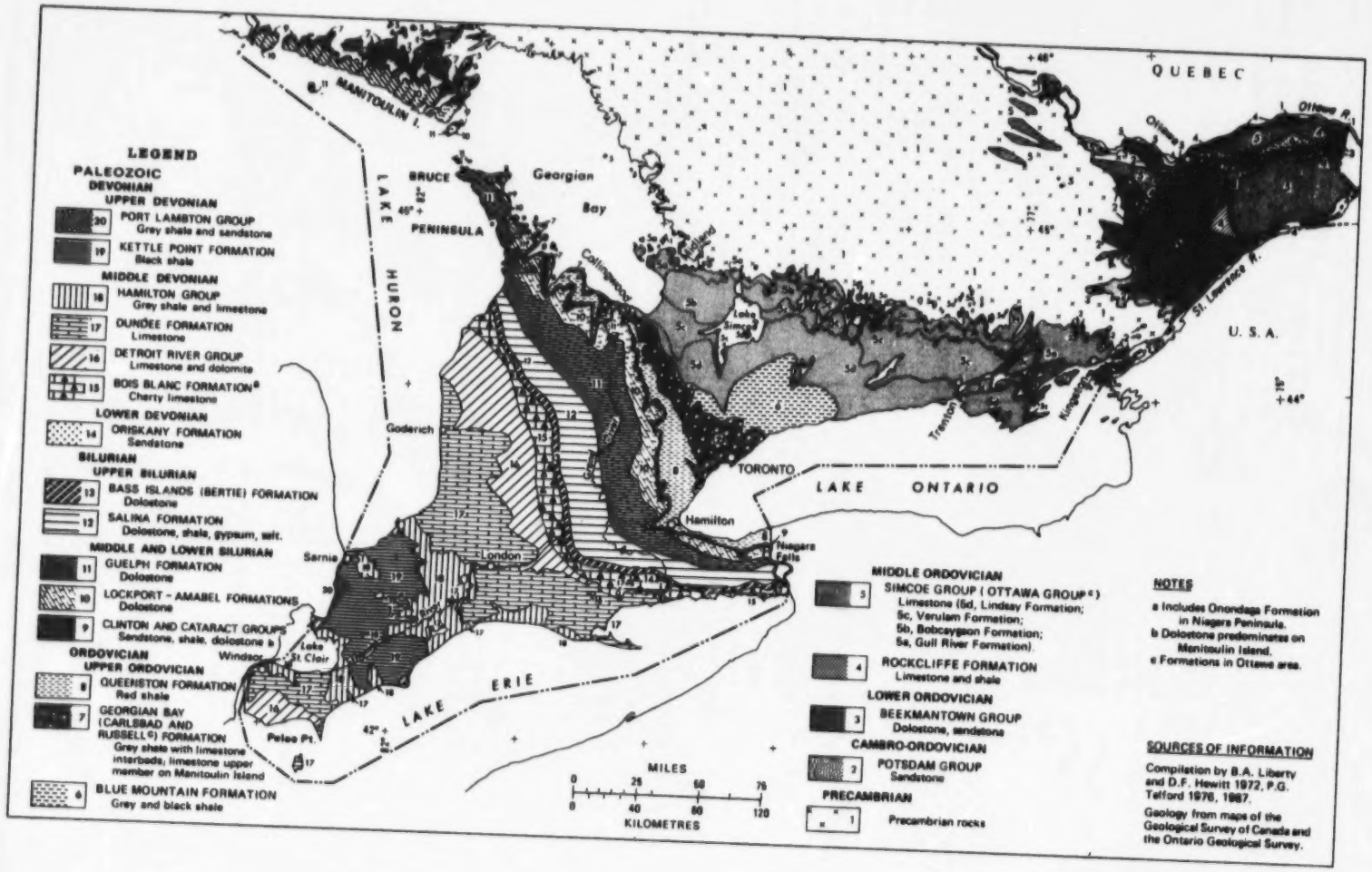

Figure D1. *Bedrock Geology of Southern Ontario.*

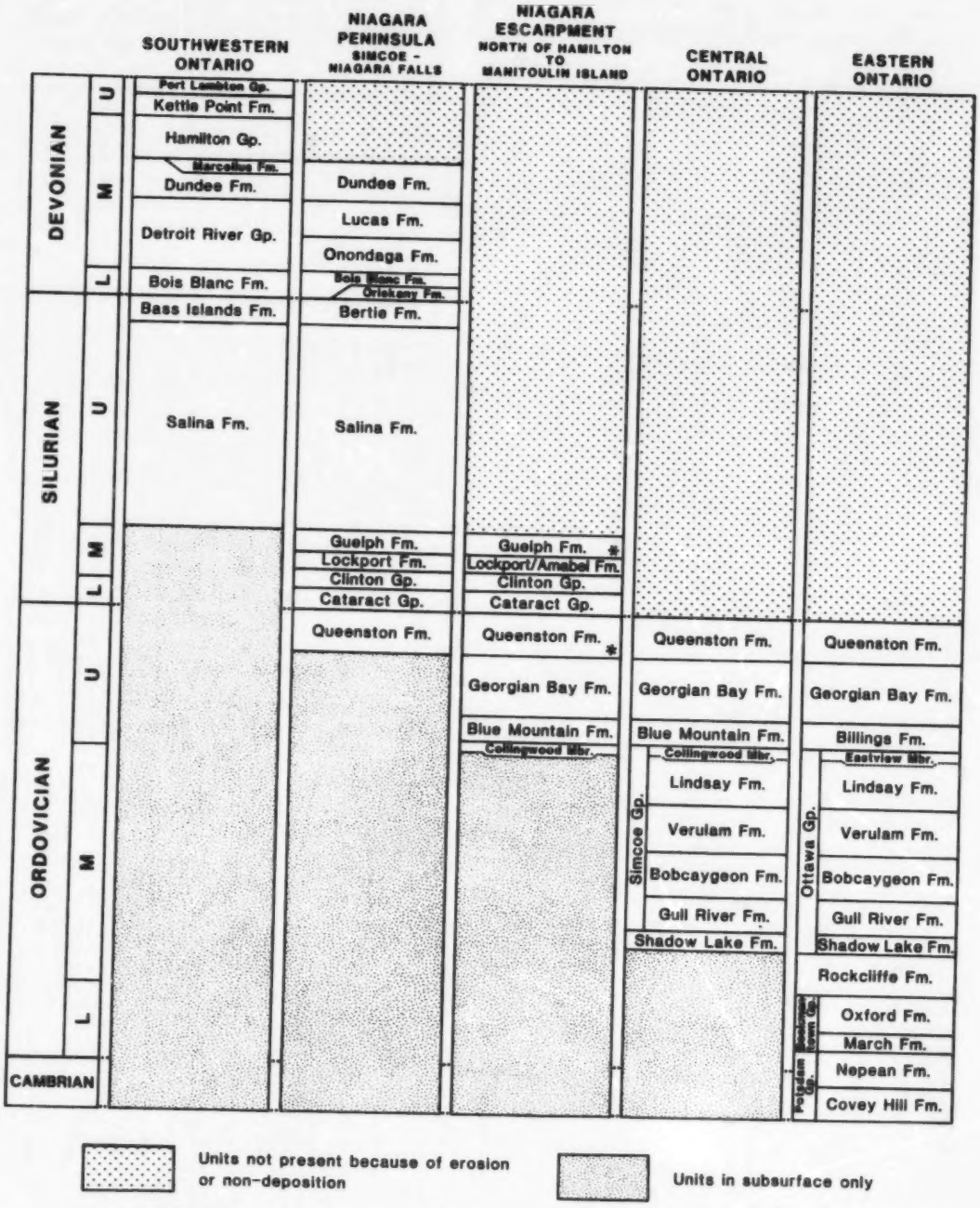

Figure D2. *Exposed Paleozoic Stratigraphic Sequences in Southern Ontario*
(adapted from: Bezys, R.K., and Johnson, M.D. 1988: The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Canadian Mining and Metallurgical Bulletin, Volume 81, Number 912, p.49-58).

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of, and the specification limits for, each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35 percent indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45 percent indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15 percent indicate potential problems for concrete and asphalt coarse aggregate.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE E1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness – Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	–	–	60	–
16 mm Crushed Type 'A'	160	–	–	35	–
16 mm Crushed Type 'B'	200	–	–	60	–
Granular Subbase B	250	–	–	–	–
Granular Subbase C	250	–	–	–	–
Granular Subbase D	–	–	–	–	–
Hot Mix – H. L. 1	100	5	1.0	15	16
Hot Mix – H. L. 2	–	–	–	–	20
Hot Mix – H. L. 3	135	12	1.75	35	16
Hot Mix – H. L. 4	160	12	2.0	35	20
Hot Mix – H. L. 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

MAPS
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CARTES
OMISES